CONTENTS

List of Illustrations and Tables  page x
Acknowledgments  xiii
Abbreviations  xv
Introduction  1

1 From the Physical World to the Biological Universe:  10
Democritus to Lowell
1.1 The Cosmological Connection  11
1.2 Philosophical Explorations  22
1.3 Scientific Foundations  29

2 Plurality of Worlds and the Decline of Anthropocentrism  36
2.1 The Anthropocentric Universe: A. R. Wallace  38
2.2 The New Universe: Anthropocentrism’s Demise?  50

3 Life in the Solar System: The Limits of Observation  59
3.1 Lowell and Mars: The Search for Intelligence,  62
1894–1924
3.2 The Search for Martian Vegetation, 1924–1957  105
3.3 Venus: Last Hope for Intelligence  126
3.4 The Space Age: Lowell’s Legacy Overturned  135

4 Planetary Systems: The Limits of Theory  160
4.1 Skepticism: Observational Hints and Stellar  162
Encounters
4.2 Turning Point: 1943–1958  180
4.3 Optimism: Observation to the Rescue?  200

5 Extraterrestrials in Literature and the Arts: The Role of  222
Imagination
5.1 The Invention of the Alien: Verne, Wells, and  223
Lasswitz
5.2 The Development and Uses of the Alien: Burroughs to  238
Bradbury
5.3 The Alien Comes of Age: Clarke, ET, and Beyond  253

6 The UFO Controversy and the Extraterrestrial Hypothesis  267
6.1 Rise of the Extraterrestrial Hypothesis  268
# Table of Contents

6.2 The Peak of the Extraterrestrial Hypothesis: 1965–1969 288
6.3 Aftermath: The Nature of Evidence and the Decline of the Extraterrestrial Hypothesis in Physical Science 307

7 The Origin and Evolution of Life in the Extraterrestrial Context 321
7.1 Arrhenius and Panspermia: An Extraterrestrial Theory of the Origin of Life 325
7.3 The Integration of Origin of Life and Extraterrestrial Life Studies in the Space Age 350
7.4 Evolution and Extraterrestrials: Chance and Necessity Revisited 389

8 SETI: The Search for Extraterrestrial Intelligence 399
8.1 Prelude: The Era of Interplanetary Communication 401
8.2 Cornell, Ozma, and Green Bank: The Opening of the Electromagnetic Spectrum for SETI 414
8.3 A Rationale for SETI: Optimists, Pessimists, and the Drake Equation 431
8.4 A Strategy for SETI: The Development of Observational Programs 454

9 The Convergence of Disciplines: Birth of a New Science 473
9.1 Perceptions of a New Discipline 475
9.2 Networks: Formation of the Scientific Community 478
9.3 Institutions: Programs and Funding 494

10 The Meaning of Life: Implications of Extraterrestrial Intelligence 502
10.1 Perceptions of Cultural Impact 503
10.2 Astrotheology 514
10.3 Life and Purpose in the Universe: The Anthropic Principle 527

11 Summary and Conclusion: The Biological Universe and the Limits of Science 537
11.1 The Triumph of Cosmic Evolution 538
11.2 The Biological Universe as Cosmological Worldview 541
11.3 The Problematic Nature of Evidence and Inference 543
11.4 The Limits of Science 546
11.5 The Cultures of Science 550
## CONTENTS

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.6</td>
<td>Exobiology as Protoscience</td>
<td>551</td>
</tr>
<tr>
<td>11.7</td>
<td>Cultural Significance of the Debate</td>
<td>552</td>
</tr>
<tr>
<td></td>
<td>Select Bibliographical Essay</td>
<td>555</td>
</tr>
<tr>
<td></td>
<td>Index</td>
<td>561</td>
</tr>
</tbody>
</table>

ix